9 Historic Role of Fire

PRIOR TO EUROAMERICAN SETTLEMENT

The presence of fire has played a pivotal role in shaping ecosystems and landscapes in the Sierra Nevada for many millennia (Davis and Moratto 1988; Smith and Anderson 1992; SNEP 1996; Anderson and Smith 1997). As a keystone ecological process it governs aspects of ecosystem dynamics such as soil and nutrient cycling, decomposition, successional pathways, vegetation structure and composition, biodiversity, insect outbreaks, and hydrology (Kilgore 1973; SNEP 1996). Historically, fire frequency, size, intensity, and severity varied spatially and temporally across the landscape depending upon number of ignitions, climate, elevation, topography, vegetation, fuels, and edaphic conditions (Skinner and Chang 1996). Fires were a common occurrence on the landscape, often burning for months at a time and reaching large sizes.

Periodic fires performed many ecological functions within Sierran ecosystems prior to Euroamerican settlement. Frequent surface fires in many vegetation types minimized fuel accumulation while their variable nature helped create diverse landscapes and variable forest conditions (Stephenson et al 1991; SNEP 1996). Fires tended to be of low to moderate severity, with high- severity portions (fire sufficiently intense to kill most large trees) generally restricted to localized areas of a fraction of an acre to several acres–infrequently larger–in size. Extensive research in mixed conifer forests has shown that low intensity surface fires were a common occurrence and tended to keep the forests open (Biswell 1961; Weaver 1967, 1974; Hartesveldt and Harvey 1967; Kilgore 1971, 1972; Harvey et al 1980).

Many species and most communities show clear evidence of adaptation to recurrent fire, demonstrating that fire occurred regularly and frequently. This is particularly true in the chaparral and mixed conifer communities, where many plant species have life history attributes tied to fire for their reproduction or as a means of competing with other biota. Fire damaged or killed some plants, setting the stage for regeneration and vegetation succession. Many plants evolved fire- adapted traits, such as thick bark, and fire- stimulated flowering, sprouting, seed release, and/or germination (Chang 1996). Fire influenced soil and forest floor processes and organisms by consuming organic matter and inducing thermal and chemical changes. It also affected the dynamics of biomass accumulation and nutrient cycling at a variety of spatial scales. These effects in turn influenced habitats, distribution, and occurrence of many species (plants, vertebrates, and invertebrates).

The near exclusion of widespread low- to moderate- severity fire beginning in the latter half of the nineteenth century drastically affected the structure and composition of most Sierra Nevada vegetation, especially low- to middle- elevation forests. The changes are widespread and the effects are still generally poorly understood. The most obvious changes are increases in tree density and changes in biodiversity (Parsons and DeBenedetti. 1979; McKelvey et al. 1996). Shade tolerant species such as white fir have increased in density over shade intolerant species such as Jeffrey pine. Forests today are denser, with a higher proportion of smaller trees, and with an increased dominance by white fir and incense cedar. These changes have increased the levels of fuel, both on the forest floor and "ladder fuels"—small trees, branches, and brush which can carry fire into the canopy. Increases in fuel, coupled with efficient suppression of low and moderate intensity fires, have led to an increase in general fire severity. Crown fires were rare or absent from Sierra sequoia- mixed conifer forests prior to Euroamerican settlement (Show and Kotok 1924; Kilgore and Taylor 1979). In contrast, in contemporary forests the probability of extensive crown fire or lethal scorch has increased significantly (Bonnicksen and Stone 1978; Kilgore and Sando 1975). The 1955 McGee and the 1987 Pierce fires in sequoia- mixed conifer illustrate these changes in the fire regime.

Fire Regimes

Attributes of pre- Euroamerican fire regimes can provide vital reference information for understanding changes in ecosystems over the last 150 years and in developing goals for the restoration of fire. The concept of a fire regime allows us to view fire as a multi- faceted variable rather than a single event within an ecosystem (Whelan 1995). Thus areas can be classified as having a certain type of regime that summarizes the characteristics of fires, within some range of variability that can have both spatial and temporal attributes. The idea also allows us to estimate if human activities have altered fire regimes, and to what extent. This information helps facilitate decision making on what management actions are needed to preserve or restore the regime. Fire regimes are normally defined according to specific variables including frequency, severity, season, duration, magnitude, spatial distribution, and type of fire (Gill 1975; Heinselman 1981). These fire regime characteristics may vary through time and across the landscape in response to climatic variation, number of lightning ignitions, topography, vegetation, specific historic events, and human cultural practices (SNEP 1996).

Common fire regime types for major park vegetation communities can be broadly defined as:

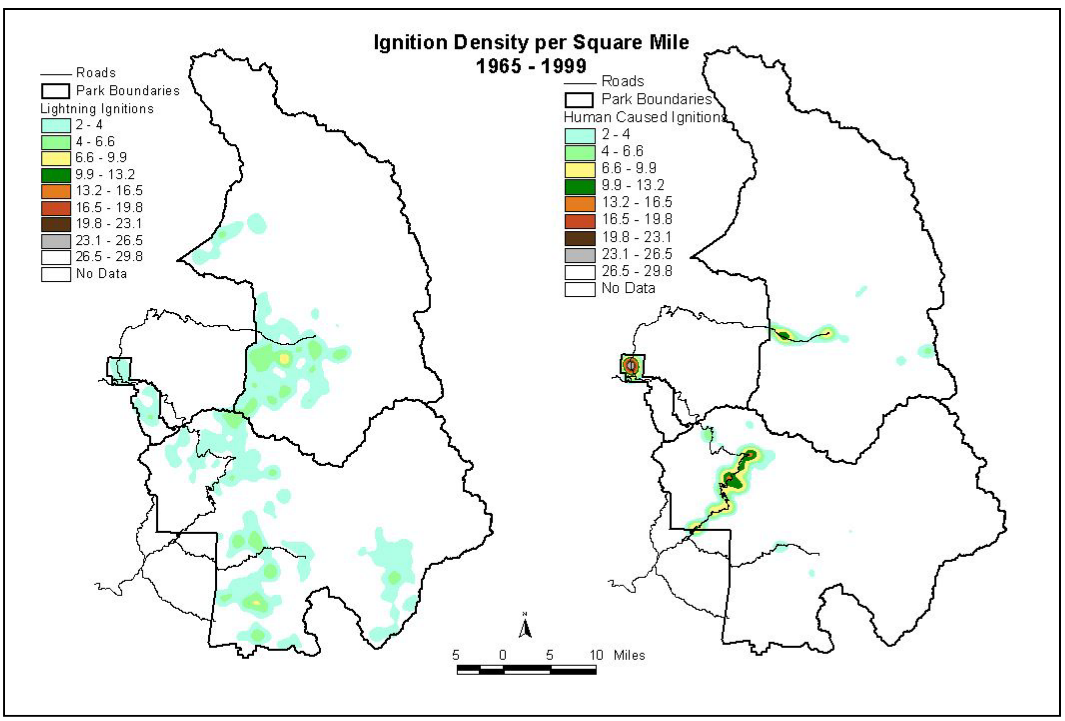
- <u>Short- interval, low- intensity surface fires</u>: These fires burn regularly and frequently and, as such, rarely allow organic fuels to accumulate to a point where high- intensity fires may develop (van Wagtendonk 1972). Examples would include ponderosa pine and blue oak woodlands.
- <u>Moderate interval, stand- replacing fires</u>: These fires occur at moderate frequencies but at high intensities. The principle example within the parks would be chaparral vegetation, where species tend to be sprouters and or obligate seeders. Increasing fire frequencies in this vegetation can result in rapid type conversion.
- <u>Variable- interval, variable- intensity surface fires</u>: These fires usually spread slowly and rarely crown. Much of the upper montane red fir forest would fall in this category.
- <u>Long- interval, low- intensity surface fires</u>: These fires usually spread slowly or not at all, and rarely burn the crowns or kill stands of overstory trees (Kilgore and Briggs 1972). Examples of this regime type in the Sierra Nevada are the subalpine forests of whitebark pine (*Pinus albicaulis*) and some foxtail pine (*Pinus balfouriana*) stands. The effects of fire vary with species, stand age, and fire intensity.
- <u>Long- interval, high- intensity surface fires</u>: These fires burn rarely, but become high- intensity, possibly stand- replacing. For the Sierra Nevada, piñon pine and juniper in the eastern Sierra might fit this category.

- <u>Long- interval, variable intensity fires</u>: These fires are uncommon events and exhibit considerable spatial variability in intensity depending on fuel and weather conditions. Infrequent fires in lodgepole pine forests (*Pinus contorta* var. *murrayana*) may be characterized by low intensity surface fires or, under severe burning conditions, high severity crown fires.
- <u>Lack of fire</u>: Within a few particular areas fire probably did not occur or its occurrence was extremely rare and erratic. Examples might include alpine vegetation and isolated foxtail pine stands (stands not connected to lower elevation forests) where if fire occurred it would usually only burn the single tree that was ignited. Evidence for the long absence of widespread fire in these stands comes from the great age of many individuals of this fire sensitive species and from the extensive amounts of subfossil wood, often exceeding 4,000 years in age, found on the ground (stands such as Alta Peak, Tablelands, or Tawny Point provide examples).

Ignition Sources

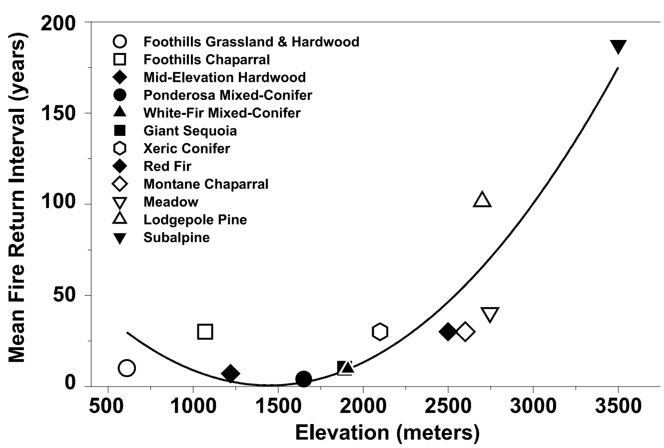
Contemporary lightning ignition rates within the parks have considerable spatially variation. Based on data from the parks' fire records over the last 70 years (Vankat 1985; NPS GIS data), ignition densities cluster in areas above Cedar Grove, the Kern Canyon, Sugarloaf Valley, and the western slopes of the Great Western Divide (Figure 9- 1). Standardizing for land area, lightning ignition rates are lower than expected at lower and at higher elevations and higher than expected at mid elevations particularly in white fir, red fir, and Jeffrey pine vegetation types. However, while contemporary lightning ignition rates are lower in lower elevation conifer areas, where historic fire return intervals were the shortest, past fire sizes at these elevations were probably greater than at higher elevations due to greater rates of fire spread.

Figure 9-1 – Maps of Lightning and Human-Caused Ignitions



Ignitions of pre- Euroamerican settlement fires are usually attributed to either lightning or ignitions by Native Americans. In the Sierra Nevada authors typically refer to a background level of lightning ignitions that were complemented by Native American sources (Lewis 1973; Kilgore and Taylor 1979). However, while there is good evidence that Native Americans started fires from a variety of sources (Reynolds 1959; Lewis 1973) considerable debate remains on the importance of this fire at a landscape scale. This burning undoubtedly influenced vegetation patterns, although probably on a local basis determined by proximity to camping, hunting, or other resource use areas. Within the parks the reasons, timing, and sizes of Native American burning are poorly understood. Current hard historic evidence on the source of fires in the southern Sierra Nevada is too limited to determine the specific importance of either lightning or Native American causes. Actual patterns of fire across the landscape were probably a result of both ignition sources with the importance of each varying between specific vegetation types and locations. However, within the parks it is argued that the number of lightning ignitions could account for the observed pre- settlement fire frequencies if they had not been suppressed and had been allowed to spread (Swetnam et al 1992; Stephenson 1996; Vale 1998). This contrasts with views which suggest that lightning ignitions were not frequent enough to account for the number of fires that occurred in the Sierra prior to Euroamerican settlement (Reynolds 1959; Vankat 1970; Lewis 1973; Kilgore and Taylor 1979). The former view is supported by an analysis of past fire occurrence, reconstructed using fire scars, and contemporary lightning ignitions in the East Fork watershed (Caprio 2000 unpublished data). For the period from 1750 to 1849 fires were recorded during 75% of the years (25% without fires) while during the contemporary period from 1933 to 1999 lightning ignitions (243 total) were recorded for 79% of the years (21% without ignitions), a very similar frequency. While specific locations within the watershed had high pre- Euroamerican settlement fire frequencies and few recent ignitions there are no apparent barriers to fire spread from areas with high ignition rates.

Figure 9-3 – Relationship Between Fire Frequency and Elevation



Fire Frequency

General patterns of pre- Euroamerican fire frequencies are apparent at several scales within the parks. Variation exists locally, with specific site characteristics such as productivity, potential for ignition, or other factors influencing frequency. General patterns are also apparent at large scales. For example differences in average fire frequency are apparent in different vegetation types (Table 9- 2, next page). Additionally, on the west slope of the Sierra, frequencies reconstructed using fire- scarred trees show an inverse relationship between number of fires and elevation (Caprio and Swetnam 1995; Swetnam et al 1998; Caprio 2000). When all available information about fire occurrence for all major vegetation types in the parks (including vegetation types where fire scars are not found) are considered the relationship between fire frequency and elevation has a pronounced "Lazy- J" shaped relationship (Figure 9- 3) (Caprio and Lineback 1997). Fire return intervals are longest at higher elevations, shortest in lower mixed conifer forest and appear to again increase in length in lower elevation grass- oak woodland and chaparral vegetation based on current, albeit poor quality, information.

Table 9-2. Fire Frequencies for Different Vegetation Types.

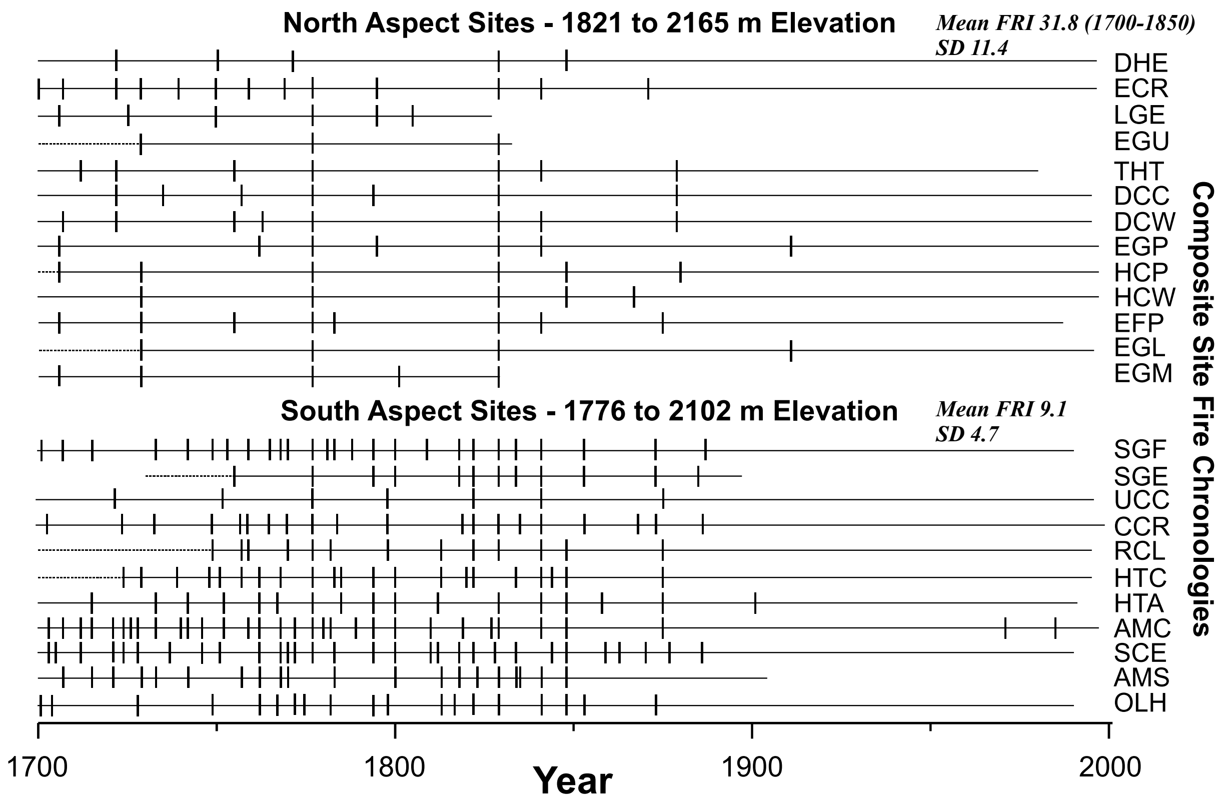
Mean and maximum fire-return intervals for the 12 major classifications in Sequoia & Kings Canyon National Park. Data are for the period prior to 1860 (1870 for subalpine conifer). The primary source(s) for the data are enumerated under "Reference" heading and are listed at the bottom of the table. Fire frequency regime classes for each major vegetation class were based on mean maximum fire-return intervals. The frequency classes were used to reconstruct fire frequency regimes spatially across the park.

Vegetation/Terrain Class (class code #)	Code	Mean	Max.	Freq. Class	Knowledge	Reference
(1) Ponderosa Mixed Conifer	PIPO	4	6	v. high	good	1,2,3,16,177
(2) White Fir Mixed Conifer	ABCO	10	16	high	good	1,2
(3) Red Fir Mixed Conifer	ABMA	30	50	low	poor	1,4,5
(4) Lodgepole Pine Forest	PICO	102	163	v. low	v. poor	5,6,18
(5) Xeric Conifer Forest	XECO	30	50	low	v. poor	5,7,8,17
(6) Subalpine Conifer	SUAL	187	508	v. low	poor	5,9
(7) Foothills Hardwood & Grassland	FHGR	10	17	mod.	v. poor	5,10,11
(8) Foothills Chaparral	FOCH	30	60	low	estimated unknown	12
(9) Mid-Elevation Hardwood	MEHA	7	23	mod.	v. poor	3,19
(10) Montane Chaparral	MOCH	30	75	low	estimated unknown	12
(11) Meadow	MEAD	40	65	low	estimated unknown	8
(14) Giant Sequoia Forest	SEGI	10	16	high	good	13,14,15
(12) Barren Rock	ROCK					
(13) Other (mostly water)	OTHR					
Missing Data	MISS					

1 Caprio and Swetnam 1993, 1994, 1995; **2** Kilgore and Taylor 1979; **3** Stephens 1997, unpublished data in Skinner and Chang 1996; **4** Pitcher 1981,1987; **5** Caprio unpublished data 2000 ; **6** Keifer 1991; **7** Taylor, unpublished data in Skinner and Chang 1996; **8** Skinner, unpublished data in Skinner and Chang 1996; **9** Caprio, Mutch, and Stephenson unpublished data ; **10** Mensing 1992; **11** McClaren and Bartolome 1989; **12** SNEP 1996; **13** Swetnam et al. 1991; **14** Swetnam et al. 1992; **15** Swetnam 1993; **16** Warner 1980; **17** McBride and Jacobs 1980; **18** Sheppard 1984; **19** Stephens 1997

Additionally, within at least some watersheds strong differences in fire frequency exist between aspects. In the Redwood Mountain area, which is sequoia- mixed conifer, fire occurred about every nine years on west- facing slopes and every 16 years on east- facing slopes before 1875 (Kilgore and Taylor 1979). In the East Fork differences are more pronounced with fire 2- 3 times more frequent on south than on north aspects at similar elevation sites (Fig. 9- 4) (Caprio 2000).

Figure 9-4 – North and South Aspect Fire Frequencies in the East Fork



Another important component of fire frequency statistics is the stochastic variation in fire intervals through time (fire interval distributions) among or within vegetation types. For example, areas with a similar mean fire return interval could have quite different fire interval distributions. One site might have very regular intervals between fires while a second site might have very irregular intervals. Such interval dependent effects of fire events can have significant influences on plant demographics and long- term plant community structure (Whelan 1995; Bond and van Wilgen 1996; Chang 1996).

Magnitude
Fire characteristics, such as intensity and severity, also varied among vegetation types. At lower elevations, little is known about fire regimes in grasslands and oak woodlands due to the lack of fire scarred trees and the replacement of nearly all native herbaceous communities by exotics following initiation of intense grazing in the 1860s (Dilsaver and Tweed 1990). However, descriptions of the vegetation suggest that episodic fast moving surface fires in flashy herbaceous fuels, during the dry summer/fall, probably played a role in these communities (Parsons 1981). Stand replacing fire in chaparral communities today probably differs little from pre- Euroamerican characteristics although frequencies have probably been altered. In much of the Sierra's sequoia- mixed conifer forest, fires were primarily non- stand replacing surface fires prior to Euroamerican settlement (Show and Kotok 1924; Kilgore and Taylor 1979; Warner 1980; Pitcher 1987; Caprio and Swetnam 1995). Instances of large stand replacing fires do exist in particular mixed- conifer locations (Caprio et al 1994). Fires in these areas were dominated by low to moderate severity, with high- severity generally restricted to localized areas (Stephenson et al 1991). Characteristics of past fire appear to have been somewhat different in higher elevation forests. Fire in red fir forest was typically non-stand replacing due to the fire resistant bark of this species but significantly sized patches of trees could be killed, particularly on higher elevation north aspects (Pitcher 1981; 1987). Fire in lodgepole pine was generally a patchwork of low intensity surface fire and higher intensity crown fire depending of specific burning conditions.

Fire Size
The scale of fire prior to Euroamerican settlement was significantly different from what is typically observed today. Both the frequency of fire occurrence and the frequency of large spreading fires were much greater than today or at any time in the last hundred years. Estimates based on fire history data suggest that from 15,100 to 24,700 acres burned annually within the parks (Caprio and Graber 2000). However, because of the vagaries of climate or number of ignitions, the actual number of acres burned in any given year could have been much greater or much smaller than the average. Coarse reconstructions of actual pre- Euroamerican settlement fire sizes in the Kaweah's East Fork watershed indicate that up to ~10,400 acres (33%) of the 31,870 acre watershed burned in a given year (this may have been one or more fires in the year 1829) (Caprio 2000). Of interest is that some of these fires also burned in adjacent drainages. For example fires in 1777, 1812, and 1841 are all recorded in the South Fork, East Fork, and Middle Fork of the Kaweah River, indicating potential spread of fires among watersheds. However, most fires were small with a roughly estimated annual area burned of ~800 acres (2.4% of the area) in the East Fork.

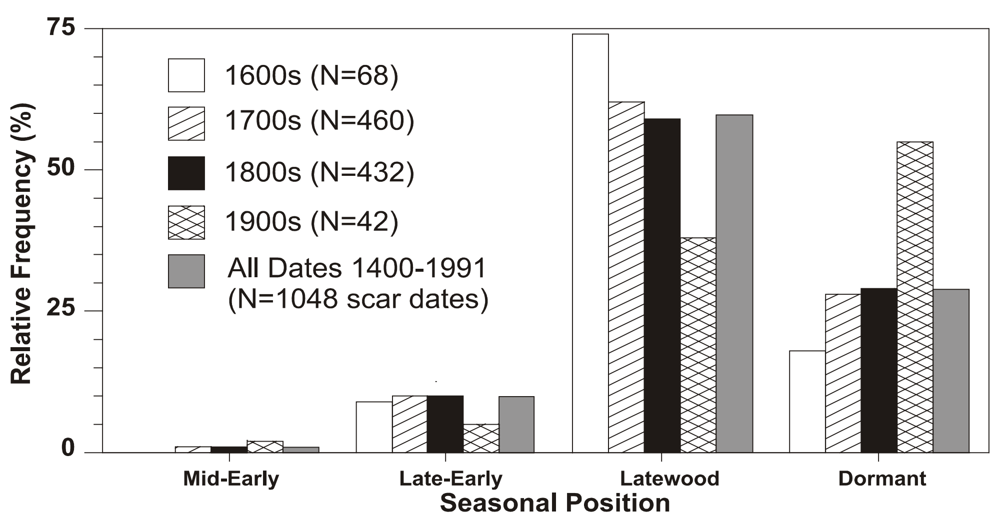
Fire history reconstructions suggest that variation in fire size also occurred by aspect (Caprio 2001, in review). Within the East Fork watershed annual area burned prior to Euroamerican settlement on lower south aspects (5,860 – 7,145 feet elevation) was generally small but regularly interspersed with years when moderate large fires occurred. In contrast, on similar north aspects most fires seem to have been small but the pattern was punctuated by rare years when large areas burned.

Fire size was probably also related to overall landscape diversity patterns such as vegetation, fuel, and topographic complexity. In course- grained landscapes, such as the highly dissected, rocky high country (upper Kern and Kings River drainages) fires probably tended to be smaller with poor year- to- year synchrony. In contrast, fires were probably larger and more synchronous in fine- grained watersheds such as are found on the west side of the range. Burn patterns in these landscapes would be related to fire conductance among vegetation types and between drainages. For example, in the Kaweah watershed, fires would have the potential to spread for long distances during the long summer/fall dry season. Additionally, drainages such as the Kaweah have strong connections to lower elevation grasslands (now outside the parks) where ignitions could spread rapidly and reach large sizes before spreading into conifer forests.

Seasonality

Season of fire occurrence can have important effects on vegetation and wildlife. Factors that can be important in seasonality are fuel moisture content, phenology of vegetation, or life history patterns of wildlife. Vegetation and wildlife within particular ecosystems have generally adapted to fire within a particular window of time. Changes in seasonality that go outside the normal range of variability may have adverse impacts. In the Sierra Nevada pre- Euroamerican settlement fires generally occurred from the summer through the fall based on analysis of seasonal positions of fire scars in tree rings (Swetnam et al 1992; Caprio and Swetnam 1995) (Figure 9- 5). This agrees with current knowledge of contemporary lightning ignition and fire spread patterns (Show and Kotok 1924; Vankat 1985; Sequoia and Kings Canyon fire records).

Figure 9-5 – Seasonal Position of Fire Scars by Century



Effects of Climate

Short- term climatic variation played a very strong role in influencing burn patterns and fire severity in the past. Historically, on the west slope of the Sierra Nevada specific regional fire years have been identified (years in which fires have been recorded at sites from throughout the southern Sierra Nevada). These usually occurred during dry years (Brown et al. 1992; Swetnam et al 1992; Swetnam 1993; Swetnam et al 1998). The reconstruction of fire size in the East Fork watershed indicates large fires, burning throughout the watershed, primarily occurred during years when prior winters were dry while small to moderate sized fires could occur on south aspects during almost any given year (Caprio 2000). Analysis of millennial length fire histories from giant sequoia also document long- term variation (1,000- 2,000 years) in the fire regime associated with climatic fluctuations (Swetnam 1993). These data suggest more frequent but smaller fires during the Medieval Warm Period (A.D. 1000 - 1300) and fewer larger fires during cooler periods (A.D. 500 - 1000 and after A.D. 1300). These fluctuations indicate that characteristics of fire regimes are dynamic over long time periods. Thus long- term management should not be based solely on a static interpretation of the fire regime for a particular unit of land at a given time.

POST-EUROAMERICAN SETTLEMENT CHANGES

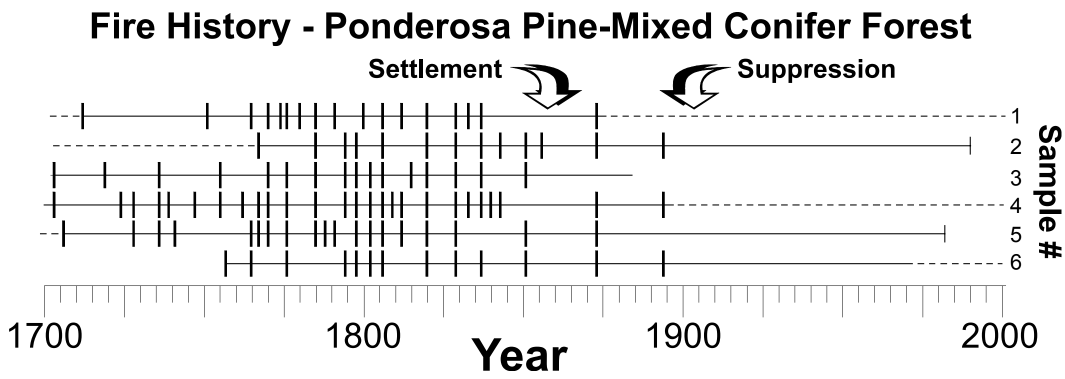
Literature on changes to pre- Euroamerican fire regimes often suggests that changes in these regimes are largely the result of active fire suppression activities. However, fire history reconstructions show that the most dramatic changes in Sierran fire regimes took place 40 to 70 years prior to the initiation of organized and effective suppression efforts in the first two to three decades of the twentieth century. By far the most dramatic changes appear to be a direct result of initial Euroamerican utilization and settlement of the southern Sierra between about 1850 and 1880.

Reconstructions of past fire occurrence from fire scarred trees in the parks show several periods of change between 1850 and 1921 (when written fire records for the parks begin). Between about 1850 and 1870 a dramatic decline in fire frequency occurred in nearly all lower to mid- elevation conifer forests. Between about 1870 and 1900 large landscape scale fires continued to burn although at a reduced frequency relative to pre- Euroamerican levels. Similar changes may have also occurred in lower elevation vegetation but fire history evidence is lacking in these vegetation types. In upper elevation areas, changes are also not apparent during this period due to the long natural fire return intervals. In the first decades of the twentieth century fire on the scale that had occurred prior to 1900 no longer existed.

The initial change in local fire regimes in the 1860s appears to be the result of either: 1) a decline in the influence of Native American populations and/or 2) the impact of intense grazing pressure on fine fuels, particularly at lower elevations, important for fire spread (Vankat 1970; Caprio and Swetnam 1995).

Literature on fire and human impacts on the Sierra Nevada during the latter half of the 19th century often mentions the extent and impact of fires set by sheep herders (Vankat 1977; Beesley 1996; Kinney 1996). The indicated purpose of the burns, set in the fall as the flocks moved out of the mountains, was to improve forage and remove barriers to sheep movement. It is also frequently mentioned that fires were of unnatural intensity (Muir 1877; Muir 1938). However, this picture of large scale burning by shepherds is not supported by the fire history sampling that has been carried in the parks or other locations on the western slope of the southern Sierra (Swetnam et al 1992, Caprio and Swetnam 1995; Swetnam et al 1998; Caprio 2000, unpublished). Of the large number of fire history chronologies developed in this area nearly all show a dramatic decline in fire frequency in about 1860 (Figure 9- 6). While sporadic fires, which continue to appear in the fire scar record up until about 1900, could have been set by shepherds their ignition source(s) remains unknown.

Figure 9-6 – Decline in Fire Frequency Around 1860



Effectiveness of fire suppression in the first half of the twentieth century varied spatially over the landscape. Suppression efforts had their greatest impact in the middle- elevation zones where low- to medium- intensity surface fires were more easily controlled. In contrast, fast- spreading fires typical of chaparral sites were often beyond the control of humans and were less successfully suppressed (Chang 1996). Fire records from in and near the parks show a substantially higher proportion of large fires in grass/oak woodland and chaparral than in mid-elevation conifer forest through the 1930s. Active fire suppression of all fires continued until 1968 when the first large scale prescribed burn was carried out in the parks. This was soon followed by a policy shift that permitted some lightning ignitions to burn naturally. Since 1968 a substantial amount of area has been burned either through active management ignitions or lightning ignitions allowed to burn (Figure 9- 7).

Figure 9-7 – Area Burned Through Active Management or Lightning